THE INTERNATIONAL GRANITE QUARRY.

The quarry is situated on Grindstone Island, one of the far-famed Thousand Islands. It is distant from the town of Clayton, N. Y., four miles, and the same distance from Gananoque, on the Canada side. The altitude of the quarry is 62 ft. above high-water level, and contains stone enough to last many generations. In color the stone is of a beautiful jasper; and it is capable of taking a very high polish. It is much sought after for monumental and other purposes, being preferred for its beauty of color and durability to any red granite on this continent. It was from this quarry that the large columns supporting the roof of the Senate Chamber at the New Capitol, at Albany, N. Y., were procured. The Superintendent informs us that stones of any size can be obtained from it. The proprietor, R. Forsyth, of Montreal, purchased the quarry four years ago, and has laid out a large sum of money in developing it.

A SYSTEM OF DESIGNING HIGHWAY BRIDGES.*

[Before commencing this paper the writer wishes it to be understood that he does not consider the system here given to be the only correct one in existence, nor does he even claim that it is the best. It has been prepared by him for Messrs. Raymond & Campbell, bridge builders, of Council Bluffs, Iowa, and it is owing to their courtesy that he is now permitted to present it to the public.]

Ordinary highway bridges may be divided into two classes; those for use in cities, towns and their suburbs, where they will be subjected to heavy loads, and those for country roads, where the loads are necessarily lighter. The former for spans of 60 ft. or less should be proportioned to carry a load of one hundred pounds per square foot of surface, and for those above 60 ft. the load may be diminished gradually to seventy-five or even sixty pounds per square foot for spans of 200 ft., the working stress per square inch for iron in tension being usually five tons, though sometimes six and a quarter.

For country bridges the load varies from eighty to fifty pounds per square foot according to locality and length of span, the working stress per square inch for iron in tension, in nearly every case, being six and a quarter tons.

Some bridge companies have employed seven and a half tons, but this is now generally considered to be injudicious. The reason why long spans may be proportioned for lighter loads than short ones is the very small probability of a long span ever being entirely covered by the maximum load, while there is a chance of such an event taking place in case of a short span. It can easily be seen, then, that in all bridges of *any length* of span each panel should be proportioned to sustain the maximum load, for it is possible to load one panel heavily without loading any of the others.

This panel excess will affect only the sizes of the joists, floor-beams and beam hangers. Sometimes the panel excess is supposed to exist when the bridge from the nearest end up to the panel considered is covered by the moving load, which would affect also the sizes of the counters. This last requirement is very seldom taken into account.

Owing to the fact that there are far more country than city bridges built, the writer has paid more attention to the former than to the latter; and of the twenty tables which accompany this paper† two only (Nos. II. and XVIII.) are especially for city bridges, twelve (Nos. V.–XVI.) are especially for country bridges, while the remainder (Nos. I., III., IV., XVII., XIX. and XX.) may apply to either. On account of the great variation in the data for city bridges, it would require more labor to systematize them and tabulate the dimensions of their floor systems, as has been done for the country bridges in Tables V. to XVI. inclusive, than the number of city bridges to be built would warrant.

Each of the two classes of bridges is subdivided into three kinds—iron, combination and wooden. The last-mentioned will not be treated here, for, on account of the inferiority of wood for tension members, that style of bridge is fast passing out of existence.

At present there are probably more combination bridges being built in the West than there are iron or wooden ones. The reason is that the first cost of a combination bridge is but little more than half that of an iron one, and that, if properly cared for, it will last from twelve to twenty years, or even longer. By covering the chord and batter braces with sheet iron or shingles, several years may be added to its life.

The first step to take in making a design, is to make out a table of data for calculating the diagram of stresses. The form employed by the writer is as follows:

Single Intersection.	Double Intersection.
$n =$	$n =$
$l =$	$l =$
$d =$	$d =$
$diag =$	$short\ diag =$
$sec\ \Theta =$	$long\ diag =$
$tan\ \Theta =$	$sec\ \alpha =$
$w =$	$tan\ \alpha =$
$W_1 =$	$sec\ \beta =$
$W' =$	$w =$
$W'' =$	$W_1 =$
$W =$	$W'' =$
$-\frac{1}{n} w =$	$W' =$
$-\frac{1}{n} w\ sec\ \Theta =$	$W =$
$W_1\ sec\ \Theta =$	$-\frac{1}{n} w =$
$W''\ tan\ \Theta =$	$-\frac{1}{n} w\ sec\ \alpha =$
	$W_1\ sec\ \alpha =$
	$-\frac{1}{n} w\ sec\ \beta =$
	$W_1\ sec\ \beta =$
	$W''\ tan\ \alpha =$

where n is the number of panels, l the length of each panel, d depth center to center of chords, Θ the inclination of diagonal ties to vertical, w live load per panel one truss, W_1 dead load per panel on one truss, $W'' = w + W_1$, W' the portion of W_1 concentrated at upper panel point, W the portion of same concentrated at lower panel point, α the inclination of short diagonal tie to vertical, and β the inclination of long diagonal tie to vertical. Of these quantities l, n and d are usually to be determined by experience. Of course the length of span, width of roadway, and the live load per lineal foot are given; from these six quantities the rest of the table of data can be determined, although it may take several trials to find the dead load per lineal foot of bridge, from which W_1 is calculated. It is difficult to give directions for finding the dead load, but the writer hopes at some future time to treat that subject by itself. For the present, the following approximate and incomplete table must suffice; pine being figured at two and a half and oak at four and one-third pounds per foot, board measure.

Iron Bridges 60 ft. Clear Roadway, Lumber all Pine.

Length of span.	Dead load per lineal ft. on both trusses.	Live load per sq. ft.
Feet.	Lbs.	Lbs.
75	400	80
100	456	80
140	528	80
155	530	70
155	562	80
200	624	60

When pine floor and joists are used, the flooring being 3 in. thick, the average weight of lumber per lineal foot is 235 pounds; where oak floor and joists are used, the flooring being 2½ in. thick, it is 810 pounds.

For different widths of roadway the dead load will vary almost directly as the widths. Combination bridges of same span, roadway and moving load are from 7 to 10 per cent. heavier than iron ones.

In regard to the best values for n and d there is considerable difference of opinion among bridge builders. It is probably economical to employ long panels, though there seems to be an unfounded prejudice against them among most county commissioners and a few builders. It is probable, too, that greater depths of trusses than those generally used would be economical.

He employs the following proportions:

Span.	Depth of Truss.	Remarks.
30	4′	No side braces.
40	5′	" "
50	6′	" "
60	7½′ to 10′	Above 7½′ use side braces.
60	15′	Through bridge 4 panels.
80	16′	5 panels.
100	20′	5 panels.
125	25′	Vertical sway bracing.
150	25′	" "
175	28′	" "
200	30′	" "

As for the length of span at which it is economical to change from the single to the double intersection, this, too, is not yet fixed, but is probably about 140 ft.; this point will also be settled at the same time with the values of n and d.

Suppose, then, that the table of data is filled out; the next step is to find the stresses in the different members of the truss; the method for which, having received so much attention from various writers, will not be treated here. There is one point, however, that ought to be mentioned, viz.: that it is customary to subtract the effect of the dead from that of the moving load in each panel, when calculating stresses in counters. Professor Burr advises the contrary, for the purpose of keeping on the side of safety. This object is usually attained by straining iron to a less extent in the counters than in the main diagonals.

The hip verticals are usually strained to the same extent as the counters, viz.: four tons, when the main diagonals are strained five, or five tons when they are strained six and a quarter.

Having found all the stresses in the members of the truss, the next step is to calculate the sections. Let us suppose the bridge under consideration to be an iron one. First, find the areas of all the tension members and write them on the diagram immediately after the corresponding stresses, prefixing the areas with the letters *S R* (section required), then by the use of Carnegie's "Pocket Companion," pp. 88–109, ascertain the sizes necessary to give *at least* the section required, taking care that the sections are in good proportion.

The best proportion for chord bars is about one to four (width = 4 × thickness), a larger fraction causing an increased bending moment on the pin, and a smaller one being liable to increase its size on account of the limiting ratio of diameter of pin to depth of chord bar. For convenience in obtaining economical and standard sizes it is often preferable to vary from this ratio, even if it does affect the pin.

The same remarks apply to the main diagonals. Counters are usualy made square or round on account of the turn-buckles; it is better in most cases to make them double, though if they be small, single ones will do. Sometimes both single and double counters are employed in the same truss. Where there is an odd number of panels, the center diagonals should be made double and adjustable.

The sections of the tension members being determined, next comes the arrangement of the bottom chord. In small bridges all the diagonals, counters, chord bars and beam hangers can be packed between the post channels, but in larger ones some of the chord bars and often the diagonals (especially in double intersection bridges) have to be placed outside.

Compression members can be made of various sections, but the most common shape is the channel bar; the top chord and batter braces being composed of two of them with a plate on top and latticing or lacing below, and the posts of two, latticed or laced on both sides. For all but very small bridges—pony trusses—these shapes are the most economical and satisfactory. A single I beam for a post in a large bridge is not economical, for there is too much material near the neutral surface; it can be used to advantage, however, in small bridges, as in that case the waste of material is more than counterbalanced by the saving in shop work. For spans of 30 ft. and under, the I beam can be used advantageously in the chord and batter braces. It is often used for upper lateral struts, but because of the difficulty in making a neat connection, it is preferable in nearly every case to employ channels for that purpose. Four-inch six-pound channels are about as small as should be used, for 3-in. ones are too much cut up by the rivet holes.

In low pony trusses the use of side braces can be avoided by making the posts of two tee irons laced and spreading them outward from top to bottom. In combination bridges star iron is often employed in the same manner.

When used in this way, the tee and star irons should be made larger than theory would show, because of the initial tension in the counters, and other causes.

To proportion the top chord or batter brace for a given stress, where two channels and a plate are to be used, assume the depth of the channel and divide the length of panel by that amount, both numbers being expressed in the same unit.

Referring to table XVII. or XVIII., as the case may be, look down the column marked "Ratio of L to D," until the ratio just found is reached; the number to the right in one of the three columns is the working stress to be used. The three columns are for the three cases; both ends fixed, one end fixed and one hinged, and both ends hinged. These tables are calculated by the formulæ of C. Shaler Smith, C. E., to whom the writer is indebted for their use and for other valuable information in connection with bridge work.

The area of the top chord or batter brace is found by dividing the stress given on the diagram by the working stress taken from the table. From this area subtract that of the top plate and divide the remainder by two; the quotient is the area of each channel.

The thickness of the top plate should not be less

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†Although these tables are of great value, our limited space prevents our printing them. At the end of the article will be found the headings of the tables. The tables can be had by sending to the Secretary of the Pi Eta Scientific Society, Troy, N. Y., and remitting twenty-five cents.

than ⅛" nor greater than ⅜". If made $\frac{1}{16}$", as is sometimes done, it is liable to be twisted out of shape while being transferred from the shop to the bridge site. It used to be customary, and the practice is still followed to some extent, to make the top plate of varying thickness, increasing from the ends of the truss to the center, making the channels of the same size throughout; but this method is not advisable, for the proper place for the larger part of the material in a chord like the one under discussion is in the channels and not in the plate. Similarly in any channel, the proper place for the larger part of the material is in the flanges and not in the web, the reason being in both cases that the moments of inertia of the section in respect to vertical and horizontal axes are increased by removing a portion of the area away from the neutral axes. The width of the top plate is dependent upon the depth of the channels and often also upon the manner of packing the bottom chord. The transverse distance between the center lines of the rivets, which attach the channels to the plates, should be never less and not (unless there be good reason) very much greater than the depth of the channels.

The chord channels are sometimes spread apart in pony trusses so as to increase the lateral stiffness, and in any bridge it may be necessary to spread them a little to admit of a certain manner of packing below.

After finding the area of one channel in the chord, look in the table of channel sections employed and see if there be a *light* channel of this area; if not it will be necessary to assume a new depth of channel bar and proceed as before.

The greater the depth of channel, the less the ratio of length of strut to diameter, and consequently the greater the working stress and the less the cross-section, so it is well to use always the lightest and deepest channels posible.

Another reason for doing so is, that in the light channels there is relatively more material in the flanges than in the heavier ones.

It is usual, but not absolutely necessary, to make the depth of the channels in the batter braces the same as that of those in the chords.

A slight difference in these dimensions will affect only the bevel in the hip joint. The posts are figured in a similar manner to the chords and batter braces, except that there is no plate; they are calculated for two-hinged ends, or one end fixed and one hinged, according to the detail employed in the upper post connection.

Next comes the determination of the sizes of the pins and the thicknesses of the reinforcing plates.

Next comes the proportioning of the floor-system. For ordinary highway bridges, tables V. to XVI. will give all the necessary results without calculation; it is unnecessary to give any directions in regard to the use of these tables, for they are self-explanatory. The joists, of which tables V. and VI. give the sizes, were figured from tables III. and IV., which were calculated by Trautwine's formula for wooden beams subjected to a deflection of $\frac{1}{315}$ of the span.

Tables VII., VIII., IX. and X. were also figured from tables III. and IV.

Tables XI. and XII. were partially taken from Carnegie's "Pocket Companion," and partially calculated by the formula for built beams $H = \frac{W \times L}{8\,D \times T} - \frac{1}{2}\,H' + H''$, where H = the area of the upper flange, W the uniformly distributed load on the beam, L length of beam in inches, D the effective depth of same in inches, or the distance between the centers of gravity of the upper and lower flanges; T the working stress for iron, in this case 10,000 pounds per square inch net section; H' the area of the web and H'' the area lost by the rivet holes. It is not necessary to add H'' for the upper flanges, but its value is so slight that it was hardly worth while to make any difference in the sizes of the angles. In large floor beams for city bridges, especially where top and bottom plates are used, it might be well to make a difference in the flange areas. In these the bottom plate need extend only half way from the center to the points of support. Care should be taken to use staggered rivets, and the areas lost by the rivet holes in the bottom plate and angles should be taken into account.

Many bridge companies reduce the depth of built beams at the ends, in order to save a little in weight of iron. This method may be advantageous to the company, but it is no saving to the manufacturer, for the triangular pieces cut from the web are wasted, and can be valued only as scrap-iron; besides, the extra work alone in cutting the web, bending the angles and making square rests for the beam-hanger nuts on the inclined flanges, more than counterbalances any saving of material. Tables XIII. and XIV. are to be used for bridges where the traffic is light, and tables XV. and XVI. for those subjected to heavy loads. It would undoubtedly be better to adopt the two latter tables altogether, but as very few companies figure the working stress in beam-hangers at four tons per square inch, it would place one at a disadvantage where competition is close.

In calculating a floor system not given in these tables, assume the total weight of the floor and joists in a panel, and to this add the live load on the panel. Then assume the dimensions of the joists, and calculate by table III. or IV. how many will be needed; should the result separate them more than two feet center to center, it will be necessary to assume smaller joists; while should it bring them more closely together than eighteen inches, it would be better to employ larger ones. The sizes of the wooden floor beams are to be calculated in a similar manner. Should the resulting weight of lumber prove to be greatly different from the assumed weight, it will be necessary to refigure.

Iron floor beams are to be proportioned by the formula already given. The calculation of sizes of beam-hangers is too simple to need explanation.

The only difference so far, between the calculations for an iron and for a combination bridge is in the proportioning of the top chord, posts and batter braces. The sections for these members are to be found by the aid of either Table I. or II., which are calculated by C. Shaler Smith's formula, as given in "Trautwine's Pocket Book." They give the working loads for square pillars; the load for a rectangular pillar is found by taking from the table, the working load for a square pillar whose sides are equal to the least side of the rectangle, and multiplying it by the ratio of the longer to the shorter side. The bolts are placed so closely together that the chords, batter braces and posts may be figured as solid pieces of timber.

It may seem that there ought to be some distinction made between fixed and hinged ends in calculating the dimensions of wooden struts; but where the posts are well attached to castings at top and bottom there is, after all, really very little difference between the conditions of posts, chords and batter braces, regarding their fixedness.

Next comes the proportioning of the upper and lower lateral systems, which is done by supposing a horizontal plane to divide the truss midway between the chords, calculating the area per panel opposed to lateral wind pressure above and below this plane, doubling areas of truss members handhailing, hub-plank, etc., but not that of joists and flooring, adding together all the areas above the horizontal plane, and multiplying the result by the assumed pressure, to find the panel load for the upper system, and dealing similarly with those below this plane to find the panel load for the lower system. In iron bridges the "Pratt system" of lateral bracing (diagonals in tension and transverse members in compression) is employed above and below, while in combination bridges that system is used below, and the "Howe system" (diagonal wooden struts and transverse members round rods), is ordinarily employed above.

The "Howe system" is both cheaper and stiffer than the "Pratt," but of course can be employed in combination and wooden bridges only, for it is never economical to make inclined members in iron bridges to resist compression, and the verticals or transverse members, as the case may be, to resist tension.

In the "Pratt system" it is customary to attach the upper lateral rods to the pins, though other devices are sometimes resorted to, and the lower lateral rods to the floor beams, making the latter act as struts for the lower system, though the effect of wind pressure on them is seldom if ever taken into account.

The method usually adopted is faulty, inasmuch as any two adjacent rods are not in the same horizontal plane, and consequently their tendency when strained is to twist the floor beam; besides, they are attached to the web, which is the weakest and most flexible part of the beam. These difficulties may be overcome by fastening two adjacent rods to a pin passing through the web, which should be reinforced at the pin-hole, and stiffened by four vertical angle iron, placed about 6 or 8 in. on each side of the pin.

This method necessitates the use of bent eyes on the ends of lateral rods, which is objectionable if the diameters be large, in which case it would be better to use four pieces of 4 in. × 6 in. angle iron, about 12 in. long, two on each side of the beam, the 4 in. legs being riveted to the web, and the 6 in. ones having holes, through which pass pins for the lateral rod attachment.

The stresses in the lateral systems are usually calculated as if the wind pressure were a fixed load, but the writer prefers to assume that it is a moving one, as that will produce larger stresses in the center and intermediate members; and in point of fact the wind is liable to strike one side of the bridge at a time.

There has been considerable discussion of late in engineering periodicals concerning wind pressure, and it has been virtually decided that thirty pounds per square foot are sufficient for long spans. The writer uses forty pounds up to 100 ft., thirty-five pounds from 100 ft. to 130 ft., and thirty above 130 ft.

Tension members in the lateral systems should be proportioned for a working stress of seven and a half tons, and the compressive numbers by tables I. or XVII. In using table I., one diagonal should be figured for the whole length, and the other, which is doweled to the first, for half length.

In many cases the stresses found in the upper system call for sections which would be practically altogether too small. No rods less than three-quarters of an inch in diameter, nor channels less than four inches in depth, should be employed.

For spans of one hundred feet the upper lateral rods should vary from three-quarters of an inch at the center to one inch at the ends, and for spans between one hundred and one hundred and forty feet the end upper lateral rod should be not less than one and one-eighth inches in diameter.

The portal bracing should in all cases be stronger than the stresses would indicate, for it is subject at times to excessive shocks. Whenever the headway will permit of its being done, the wind bracing should be extended down the batter braces, and in all highway bridges above twenty-three or twenty-four feet in height between centers of chords, there should be intermediated struts and tension members between the opposite posts. In the lower lateral system there should be placed at each end of the bridge a strut, usually of tee iron, or I beam to keep the chords apart and to transfer any stress that is not taken up by the friction of the shoe plate. The manner of determining the area of the section of the end strut is somewhat arbitrary. At the roller end it can be found by adding together the transverse component of the stress in the end diagonal and one-half a panel load of wind pressure and subtracting from the sum one-quarter of the weight of the bridge when empty, multiplied by the coefficient of friction of iron upon iron, and proportioning the strut to resist this compression. If the strut at the fixed end of the bridge be made of the same size as that at the roller end, the error so involved will be on the side of safety.

After finding the stresses in the lower lateral system, it should be observed whether the longitudinal components of the stresses in the lateral diagonals near the end of the bridge exceed the stresses due to dead weight alone in the bottom chord of the corresponding panels.

If they do, the chord bars will have to be stiffened so as to resist a compression equal to the difference between the longitudinal component of the lateral stress and the existing tension. Unless this point be attended to there is no use employing a strong lateral system, for should the latter be strained up to its working limit it would buckle the bottom chord and destroy the bridge. In nine cases out of ten this consideration is not taken into account.

Some engineers prefer to make the bottom chords stiffened throughout the whole structure and to rest the joists thereon, thus obviating the use of floor beams.

It is questionable if this method be an economical one, but undoubtedly it makes a very firm structure. The following calculations made for the case of channel bottom chords may prove useful to some one designing a bridge with transverse joints:

Let T be the tension in the bottom chord of any panel as shown by the diagram of stresses. Let l = length of panel in inches, W = distributed load in pounds resting on a single panel of the bottom chord in one truss, or in other words one-half the weight per panel of flooring and load thereon, M = maximum moment due to bending, then, as the beam is fixed at both ends and loaded uniformly, $M = \frac{1}{12}\,Wl$.

A = area in square inches of section of bottom chord in one truss, then $\frac{A}{T}$ = tension per square inch due to direct stress.

Let I = moment of inertia of A about the horizontal plane passing through the center of the channels.

R = greatest allowable stress per square inch and $R' = R - \frac{T}{A}$. Also let d = depth of channel in inches, then

$$M = \frac{R'\,I}{\frac{d}{2}} = \frac{2\,I\left(R - \frac{T}{A}\right)}{d} \qquad \therefore I = \frac{Md}{2\left(R - \frac{T}{A}\right)}$$

Now as I depends directly upon A, it will be necessary to assume a value for the latter, the depth d being decided upon at the same time, then substitute in the last equation and see if it makes both sides equal.

If not, it will be necessary to assume another value for A, substitute again, and so on, until a value be found that will make the equation hold true. Two or three trials will usually be sufficient. It is to be noticed that A is the area of the channels over and above that lost by the punching of the rivet

holes. This method is *only approximate* as it assumes the neutral surface to be at the center of the channels, but any error that there may be is on the side of safety.

To find the necessary cross section of the splice

plates, let D be the average depth of the exterior and interior splice plates shown in section in diagram, b = the sum of their widths, then the moment of inertia is approximately $\frac{1}{12}\, b\, D^3$, and the moment

$$M_1 = \frac{\left(R - \frac{T}{bD}\right) bD^3}{\frac{D}{12\,\frac{2}{2}}} \quad \therefore b = \frac{6\,M_1 + TD}{RD^3}$$

The splice plate being a short distance to one side of the panel point M_1 is a little less than M, but, if it be assumed to be the same, the error will be on the side of safety.

To the thickness thus found is to be added a small percentage for the rivet holes.

Let b' be the increased value of b, then $\frac{b'}{4}$ is the average thickness of the plates.

The thickness of the exterior plate should be a little greater and that of the interior plate a little less than $\frac{b'}{4}$.

In case bottom plates attached to the flanges be used let I' be the moment of inertia of their cross section about the middle of the bottom chord, and let A be the sum of the areas of their sections, then

$$M_1 = \frac{\left(R - \frac{T}{bD + A_1}\right)\left(\frac{1}{12} b D^3 + I'\right)}{\frac{D}{2}}$$

$$\therefore b = \frac{6M_1D - RD^3A_1 + TD^3 - 12I'R}{2RD^3} \pm \sqrt{\frac{6M_1DA_1 + 12I'RA_1 - 12TI'}{RD^4} + \left(\frac{6M_1D - RD^3A_1 + TD^3 - 12I'R}{2RD^3}\right)^2}$$

The upper sign is the one to be used, as the lower one would make the value of b negative.

To find the number of rivets necessary for the splice, suppose them arranged in two, three or four horizontal rows according to the depth of the beam, the pitch being made about two and a half times the diameter of the rivets, and the rows breaking joint.

Let p = the pitch and n = the number of rivets in the bottom horizontal plane of rivets on each side of the splice.

Let h = the diameter and a the area of a rivet and let n', h' and a' be the corresponding values for the rivets in the bottom plates. Assuming the iron in the plates, whose cross-section is A_1, to be strained up to the limit R, their resistance will be RA_1, which should equal $n'a'S$, where S is the working resistance to shearing or should equal $n'h't'C$ where t' is the thickness of the plate and C the working compressive stress per square inch.

The greater value of n' given by these equations is the one to be used.

Assuming where no flange splice plates are used that the bottom row of rivets in the side plates takes up all the stress in these plates below the horizontal plane passing half way between the two lower rows of rivets, and finding the average resistance per square inch (R'') on the portions (A_2) of the plates below this horizontal plane, under the assumption that the neutral surface lies about $\frac{1}{5}$ or $\frac{3}{8}$ of the depth of the channels from the top, $R''A_2$ should equal $2\,naS$ or $nhtC$, where t is the thickness of the web. As before the larger value of n should be taken.

It is almost needless to say that these investigations are of a very approximate character, being based upon several assumptions that are not theoretically correct.

In making out bills of material, the accompanying list of members will prove of great assistance. By their use one can avoid all possibility of an underestimate by an omission of any of the parts of the structure. A good way to make out a bill of material is to prepare six vertical columns, in the first of which write the name of the member, in the second the number of pieces, in the third and fourth the dimensions determining their section, in the fifth their length, and in the sixth the weight of all the pieces, or, if of wood, the number of feet, board measure, that they contain.

The following examples will serve to explain the method:

Bill of Wrought Iron.

Chord channels	12	7″	10½ lb.	22′	2,772 lb.
B. B. channels	8	8″	12½ lb.	33′ 9″	3,375
Plate	1	½″	12″	262′	2,620
Post channels	8	3″	6½ lb.	22′	1,144
Lateral struts	4	4″	6 lb.	15′	360
" "	4	5″	6½ lb.	15′	390
Main diagonals	8	¾″	11½″	34′	1,020
Counters	8	¾″	¾″	35′	525
etc	etc.	etc.	etc.	etc.	etc.

Bill of Lumber.

Top chord	10	17″	12″	20′	3,400
Batter brace	8	8″	14″	30′	2,240
Posts	4	9″	10″	22′	660
"	4	7″	10″	22′	513
Tie beams	2	6″	8″	18′	144
Lateral braces	2	7″	9″	39′	273
" "	4	6″	9″	39′	468
etc	etc.	etc.	etc.	etc.	etc.

It is to be noticed that it is often convenient, as in the case of the "Plate" in the "Bill of Wrought Iron," to combine several lengths into one, or as in the "Top Chord," in the "Bill of Lumber," to use one cross section ($17'' \times 12''$), instead of several ($2 - 4\frac{1}{2}'' \times 12''$ & $1 - 8'' \times 12''$).

To the length of each chord-bar, main diagonal and hip-vertical is added 3 ft. to allow for the weight of the eyes, and to that of each adjustable rod about 5 ft. Should greater accuracy be required for the latter, it will be necessary to ascertain what length of the rod is needed at each end for the connection and how much for the adjusting-nuts and upset ends, by the following table of

Equivalent Lengths of Rods for Upset Ends, Nuts, Sleeve-Nuts and Turn-Buckles.

(⅜″—1″)	— 1 upset end and 1 nut — 11 feet of rod.
(1⅛″—1⅝″)	— " " " — 1½ " " "
(1⅜″—2″)	— " " " — 1⅞ " " "
(2⅛″—2½″)	— " " " — 1 7/10″ " " "
(2½″—1½″)	— 2 up. ends and 1 s. nut — 2⅝ " " "
(1⅞″—2⅜″)	— " " 1 T buckle — 3 " " "

These equivalent lengths do not include the lengths of the upset ends themselves; they represent simply the extra length to be added to the bar to equalize the weight of the nuts, sleeve nut, or turn-buckle, and the extra iron for the enlarged ends, which are generally about eight inches long.

To estimate at all accurately the sizes of the details in order to obtain their weights, requires a knowledge of detail that can only be obtained by practice.

In some cases theory can be used to determine the sizes required, but very often some practical consideration will cause to be adopted a size different from that called for by theoretical considerations. It is not necessary in a preliminary estimate to have the exact quantities of materials; approximate dimensions will therefore be sufficient.

In making a hurried estimate of the weight of wrought iron in a bridge, it is the practice of the writer to calculate the weights of the members in the lists, under the heading "Main portions," making the allowances of extra length before-mentioned, and to divide their sum by 0.85. The result is a pretty close approximation to the total weight of wrought-iron.

Estimate of cost can be made very readily by using a blank similar to the following:

Estimate on.....Bridge across.....

.....

Length Span.....ft. Height.....ft. Clear Roadway .....ft. Static Load per lineal foot.....lbs. Moving Load per lineal foot.....lbs. No. Panels..... Length Panels.....ft.

		$	Cts.
Wrought Iron,	lbs.....@.....		
Sheet Iron,	lbs.....@.....		
Cast Iron,	lbs.....@.....		
Lumber,	ft.....@.....		
Piles,	ft.....@.....		
Hauling	.....Loads @.....		
Freight			
Framing			
False work			
Erection			
Spikes			
Painting			
Blacksmithing			
Coal			
Freight on Tools			
Traveling Expenses			
Men's Time Traveling			
Bidding Expenses			
Teaming during Construction			
Incidentals			
Total Cost of Bridge			
Cost per Lineal Foot			

A very convenient table is one giving the cost of raising and of framing bridges of different lengths of span and widths of roadway. Such a table is not given here, for each bridge company will figure the cost differently.

Estimates of cost should be liberal, for in most cases the actual profits on bridges fall short of the amounts estimated.

Table XIX. is for finding lengths and weights of lattice bars, where the section, pitch and spread are given. The lengths were obtained by diagram, so are not very exact. The table is used for *estimates only*.

Table XX. is for finding the number of rollers at an expansion joint where their diameter is given, or for finding their diameter when their number is given. Of course their length and the total pressure are known quantities. All these tables are reliable, for they have been checked either by simultaneous figuring or by the method of differences.‡

While employing the latter the writer came across a curious mathematical fact, which, though possibly known before, may be as new to others as it was to himself. Taking the expression CX^n where C is any positive number and n any positive integer and letting X increase by any constant quantity d, let us form a series, placing the numbers in their regular order in a horizontal line. Then from the second number subtract the first and place the remainder under the second number, from the third subtract the second, etc., thus forming a second series. Then treat this second series as was treated the first and so on until the n^{th} set of differences is reached, when the numbers in this set will all be found to be equal.

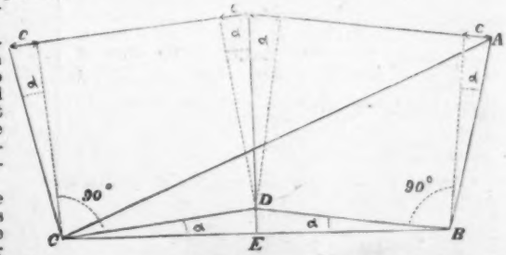
Owing to the necessary inexactness of the last decimal place, the n^{th} set of differences in checking the tables gave results, which, when the tables were properly figured, differed from each other by less than a certain quantity. It is very easy by following the series backwards to locate the position of an error.

There remains now to be discussed only the making of the working drawings, and as this paper has already exceeded the limit originally intended, this matter will be treated briefly.

The first step in making drawings for a span is to construct on a scale of say 1 in. to the foot, the skeleton of one-half of same showing the camber.

For single intersection bridges the latter, and its effect on the length of the diagonals, can be found by Trautwine's formula; for double intersection bridges the following calculations may be of use:

METHOD OF FINDING THE LENGTH OF DIAGONAL IN A DOUBLE INTERSECTION BRIDGE.



Let l = panel length in bottom chord = GD = DB.

c = ½ increase of panel length in top chord.

d = depth of truss between centers of chord = AB.

α = angle between radial line at panel pt. and ⊥ to chord.

$$\text{Then } \alpha = \sin.^{-1}\frac{c}{d} \qquad \text{(Eq. 1)}$$

$$DE : c :: l : d \quad \therefore DE = \frac{cl}{d}$$

$$BG = 2\,GE = 2\sqrt{l^2 - \frac{c^2 l^2}{d^2}}$$

$$= 2l\sqrt{\frac{d^2 - c^2}{d^2}} \qquad \text{(Eq. 2)}$$

For railroad bridges and in highway bridges of small camber BG can be taken equal to $GD + DB = 2\,GD$ without perceptibly affecting the final result.

In triangle ABG, AB and BG are known; also angle $ABG = 90° + 2\,\alpha$.

$$AB + BG : AB - BG :: tang.\ ½\,[180° - (90° + 2\,\alpha)] : tang.\ ½\,[BAG - BGA]$$

$$\therefore BAG - BGA = 2\,tang.^{-1}\left[\frac{AB - BG}{AB + BG}\ tang.\ (45° - \alpha)\right] \qquad \text{(Eq. 3)}$$

$$(BAG - BGA) + (BAG + BGA) = 2\,BAG = (BAG - BGA) + (90° - 2\,\alpha) \qquad \text{(Eq. 4)}$$

which gives BAG.

$BGA = 180° - (BAG + 90° + 2\,\alpha) = 90° - (BAG + 2\,\alpha)$.

$AG = AB\ cos.\ BAG + BG\ cos.\ BGA$ = length of diagonal required.

‡ This will be true after making the corrections indicated in the list of errata.

After finishing the skeleton, the elevation should be filled in and all joints and details drawn to a larger scale—full size if possible.

Every member in the bridge, duplicates of course excepted, should be shown in at least two projections unless the development method be employed, which is seldom advisable, as workmen have difficulty in understanding it.

The principal point to be looked after in making the drawings is to have the structure just as strong in detail as in the main members, to which end it is necessary to pay strict attention to the reinforcing and riveting.

A few rules for the latter can be found in Rankine's "Applied Mechanics" and elsewhere, but there is greatly needed an exhaustive treatise on the subject in all its detail by some well-posted mechanical engineer.

Where a pin bears against a reinforced web it is necessary to know how much of the pressure is taken up by the web and how much by the reinforcing plate or plates in order to calculate the number of rivets.

Undoubtedly that part of the bearing next to the members producing the pressure will be subject to greater intensity of stress than the parts more remote, so that if the reinforcing plate come next to those members it would not do to estimate on an uniform intensity. It is possible to figure out the intensity theoretically, but any slight imperfection in the workmanship at the pin-hole would render all the calculations useless, so it is much better to figure on the average intensity for remote reinforcing plates and to add a good percentage to same for those adjacent.

LIST OF THE DIFFERENT MEMBERS IN A COMBINATION HIGHWAY BRIDGE.

WOOD.

Top Chords.
Batter Braces.
Vertical Posts.
End Tie Beams.
End Diagonals.
Floor Beams.
Flooring.
Batter Brace Stiffeners.
Lateral Braces.
Joists.
Hand Rail Cap.
Hub Plank.
Hand Rail Post.
Felloe Plank.
Corbels.
False Caps.
Wall Plates.
Cover Boards for Chords and Batter Braces.
Lath for Same.
Cross Diagonals in Deck Bridge.
Lower Lateral Struts in Deck Bridge.

WROUGHT IRON.

Main Portions.

Main Diagonals.
Counters.
Hip Verticals.
Upper Lateral Rods.
Lower Lateral Rods.
Bottom Chord Bars.
End Lateral Struts.
Batter Brace Ties.
Star Iron Side Braces.
Cross Diagonals in Deck Bridge.
Lower Lateral Struts in Deck Bridge.
*Floor Beams.
Beam Truss Rods.

* For details of Built Floor Beams, see List of Members in Iron Highway Bridges.

DETAILS.

BOLTS.
- Chord Bolts.
- Batter Brace Bolts.
- Post Bolts.
- Bracket Bolts.
- Hand Rail Post Bolts.
- Name Plate Bolts.
- Bed Plate Bolts.
- Expansion Pedestal Fastening to Bed Plate.
- Lower Lateral Rod Bolts.
- Drift Bolts.
- Floor Beam Packing Bolts
- Beam Hangers.
- Beam Hanger Plates.
- Hip Vert. Plates on Castings.
- Lacing on Hip Verticals.
- Side Brace Connection to Chord.
- Pins.
- Side Brace Connection to Floor Beams.
- Lateral Rod Connection to Floor Beams.
- Rollers and Roller Frames.
- Jaws on End Struts.
- Dowels for Upper Laterals.
- Fillers for Pins.

Special Wrought Iron Details.

Hip Joint Boxes.
Upper Chord Panel Connection.
Lewer Post Sockets.
Pedestals.
Bed Plates.

Corrugated or Galvanized Iron.

Cover for Top Chords and Batter Braces.

Cast Iron.

Bed Plates.
Hip Joint Boxes or Hoods.
Pedestals.
Upper Post Sockets.
Upper Chord Panel Connection.
Lower Post Sockets.
Lateral Angle Blocks.
Name Plates.
Brackets.
Washer Plates for Main Diagonals and Counters.

WASHERS.
- Chord Bolt Washers.
- Batter Brace Bolt Washers.
- Post Bolt Washers.
- Upper Lateral Rod Washers.
- Lower Lateral Rod Washers.
- Beam Hanger Washers.
- Name Plate Bolt Washers.
- Bracket Bolt Washers.
- Hand Rail Post Bolt Washers.
- Bed Plate Polt Washers.
- Bevel Washers.
- Floor Beam Bolt Washers.

PACKING WASHERS
- Chord Bolt Packing Washers.
- Lateral Rod Packing Washers.
- Batter Brace Bolt Packing Washer.
- Tie Bar Packing Washers in Batter Braces.
- Post Bolt Packing Washers.
- Bracket Bolt Packing Washers.
- Floor Beam Bolt Packing Washers.

LIST OF THE DIFFERENT MEMBERS IN A WROUGHT-IRON HIGHWAY BRIDGE.

MAIN PORTIONS.

CHANNEL BARS.
- Top Chords.
- Batter Braces.
- Posts.
- Lateral Struts.
- Portal Braces.

BARS.
- Main Diagonals.
- Counters.
- Hip Verticals.
- Upper Lateral Rods.
- Lower Lateral Rods.
- Cross Diagonals on Batter Braces.
- Cross Diagonals on Posts.
- Lower Chord Bars.

PLATE.
- Top Chords.
- Batter Braces

T IRON.
- Lower Lateral Struts.

STAR IRON.
- Side Bracing.
- Hip Verts.

I BEAMS.
- Floor Beams.
- Intermediate Struts.
- Upper Lateral Struts.
- Lower Lateral Struts.
- Top Chords.
- Batter Braces.

IRON HAND RAILING.
FLOOR BEAMS.
BEAM TRUSS RODS.

DETAILS.

PLATES.

STAY PLATES.
- Top Chords.
- Ends of Posts.
- Middle of Posts.
- Ends of Lateral Struts.
- Batter Braces.
- Portal Braces.

REINFORCING PLATES.
- Hip Inside.
- Hip Outside.
- Top Chord Intermediate Panel Points Inside.
- Top Chord Intermediate Panel Points Outside.
- Bottom Chord Intermediate Panel Points Inside and Outside for Channel Bottom Chords.
- Shoe Inside.
- Shoe Outside.
- Lower Ends of Posts Inside.
- Lower Ends of Posts Outside.
- Middle of Posts Inside.
- Middle of Posts Outside.
- Floor Beam at Holes for Beam Hangers.
- Floor Beam Lateral Connections.

FILLING PLATES.
- At Panel Points of Top Chord.
- Floor Beams.

COVER PLATES.
- Shoe.
- Hip Joint.
- Intermediate Panel Points Top Chord.
- Batter Brace to Top Chord.

CONNECTING PLATES.
- Posts to Top Chord.
- Lateral Struts to Top Chord.
- Intermediate Struts to Posts.
- Portal Braces to Batter Braces.

Shoe Under Plates. — Lateral Connection to Floor Beams.
Roller Plates. — Name Plates.
Beam Hanger Plates. — Top Plate in Floor Beam.

LACING OR LATTICING.
- Top Chord Upper.
- Top Chord Lower.
- Batter Brace Upper.
- Batter Brace Lower.
- Posts.
- Lateral Struts.
- Portal Braces.

TRUSSING.
- Posts.
- Lateral Struts.
- Portal Braces.

PINS.
- Bottom Chord.
- Top Chord.
- Middle of Posts.
- Upper Lateral Connection.
- Lower Lateral Connection.
- Cross Diagonal Connection.

BOLTS.
- Bracket Bolts.
- Name Plate Bolts.
- Cross Diagonal Bolts in Batter Braces.
- Cross Diagonal Bolts in Posts.
- Bed Plate bolts.
- Expansion Pedestal Fastening to Bed Plate.
- Upper Lateral Rod Connection to Chords.
- Lower Lateral Rod Connection to Floor Beam.
- Hand Rail Post Bolts.
- Lateral Strut Connection to Chord.
- T Iron Brace Bolts.

BRACKETS FOR PORTALS INCLUDING ORNAMENTAL WORK.

T IRON BRACES
- Posts to Lateral Struts.
- Stiffeners in Built Floor Beams.

BEAM HANGERS.
EXPANSION ROLLERS.
ROLLER FRAMES.
FILLERS FOR PINS.
TURN-BUCKLES.
SLEEVE-NUTS.

JAWS.
- Upper Lateral Struts.
- Intermediate Lateral Struts.
- Lower Lateral Struts.

ANGLE IRON
- Intermediate Struts to Posts.
- Upper Lateral Struts to Chord.
- Lower Lateral Struts to Pedestal.
- Lower Lateral Struts to Chord (Channel Lower Chords).
- Batter Braces to Shoe Under Plates.
- Side and End Angles for Roller Plates.
- Angles in Built Beams.

PIECES OF CHANNELS
- Upper Lateral Strut Connection.
- Lower Lateral Strut Connection.
- Batter Brace Channel Connection to Shoe Under Plates.

WASHERS FOR HAND RAIL POST BOLTS.

RIVET HEADS.
- Top Plate to Chord and Batter Brace Channels.
- Latticing or Lacing to Channels in Top Chords, Posts and Struts.
- Latticing to Latticing in same.
- The various Stay Plates to Channels.
- The various Reinforcing Plates to Channels.
- Cover Plates to Channels.
- Connecting Plates to Channels, etc.
- Lateral Connection to Floor Beam.
- Trussing to Channels or Bars.
- Trussing to Trussing.
- Ornamental Work in Brackets.
- T Iron Braces to Posts and Struts.
- Jaws to Lateral Struts.
- The various Angle Irons to the parts which they connect.
- The various pieces of Channels to the parts which they connect.

DETAILS OF BUILT BEAMS.
- Web.
- Top Plate.
- Upper Angles.
- Lower Angles.
- Stiffening Angles.
- T Stiffeners.
- Filling Plates.
- Lateral Rod Connection.
- Reinforcing Plates at Beam Hanger Holes.
- Rivet Heads.

LUMBER.

JOIST.
FLOORING.
HAND-RAIL CAP PIECES.
HAND-RAIL POSTS.
HUB PLANK.
FELLOE PLANK.

Headings of tables accompanying the above paper:

TABLE I.—Table of working stresses in tons of 2,000 lbs. for square wooden pillars, calculated by the formula $P = \dfrac{0.625\,A}{1 + 0.004\,\dfrac{L^2}{D^2}}$ where P is equal the working stress, A the area in square inches, L the length in inches, and D the length of side of square in inches.

TABLE II.—Table of working stresses in tons of 2,000 lbs. for square wooden pillars, calculated by the formula $P = \dfrac{0.5\,A}{1 + 0.004\,\dfrac{L^2}{D^2}}$ where P is equal the working stress, A the area in square inches, L the length in inches, and D the length of side of square in inches.

TABLE III.—Table for finding the safe uniformly distributed loads that can be borne by pine beams, the loads being those which will produce a deflection of only $\frac{1}{210}$th of the span, calculated by Trautwine's formula $W = \dfrac{d^3}{16l^2}$ where W = load in tons, d = depth of beam in inches, and l = length of span in feet. To find the safe distributed load for any given beam, look in the upper horizontal line for depth of beam in inches and left hand vertical line for length of span in feet. The number found at the intersection of a vertical line through the former and a horizontal line through the latter multiplied by the width of the beam in inches will give the load required.

TABLE IV.—Table for finding the safe uniformly distributed loads than can be borne by oak beams, the loads being those which will produce a deflection of only $\frac{1}{480}$ of the span, calculated by Trautwine's formula $W = \dfrac{d^3}{11.5l^2}$ where W = load in tons, d = depth of beam in inches, and l length of span in feet. To find the safe distributed load for any given beam, look in the upper horizontal line for depth of beam and in left hand vertical line for length of span in feet. The number found at the intersection of a vertical line through the former and a horizontal line through the latter multiplied by the width of the beam in inches will give the load required.

TABLE V.—Table of pine lumber required per panel in 80-pound highway bridges, including joists, flooring, hand-rails, hub-rails, guard-rails and waste material, where pine only is employed. Flooring, 3″ thick; hand-rail posts, 4″ × 6″ × 4′; hand-rail, two pieces, 2″ × 6″; hub-rails, 2″ × 12″; and guard-rails, 6″ × 6″.

TABLE VI.—Table of pine and oak lumber required per panel in 80-pound highway bridges, where the joists and flooring are of oak and the rest pine. Flooring, 2½″ thick; hand-rail posts, 4″ × 6″ × 4′; hand-rails, two pieces, 2″ × 6″; hub-rail, 2″ × 12″; and guard-rail, 6″ × 6″. The upper figures in each rectangle are for pine, the lower for oak. The quantities include waste material.

TABLE VII.—Table of sizes of pine floor beams in 80-pound highway bridges, where pine only is employed.

TABLE VIII.—Table of sizes of pine floor beams in 80-pound highway bridges, where oak joists and flooring are employed. Flooring, 2½″ thick.

TABLE IX.—Table of sizes of oak floor beams in 80-pound highway bridges, where all the wood used, except that of the floor beams, is pine.

TABLE X.—Table of sizes of oak floor beams in 80-pound highway bridges, where the flooring and joists are of oak and remainder of pine. Flooring, 2½″ thick.

TABLE XI.—Table of iron floor beams for 80-pound highway bridges, where pine only is employed. This table is calculated on the hypothesis that the beams are so well stiffened in the direction of the trusses by the joists, that they would fail first on the side subjected to tension. Maximum stress per □″ for rolled beams = 6 tons; for built beams 5 tons per □″ net section.

TABLE XII.—Table of iron floor beams for 80-pound highway bridges, where the joists and flooring are of oak (flooring 2½″ thick) and remainder of lumber pine. This table is calculated on the hypothesis that the beams are so well stiffened in the direction of the trusses by the joists that they would fail first on the side subjected to tension. Maximum stress per □″ for rolled beams = 6 tons; for built beams 5 tons per □″ net section.

TABLE XIII.—Table of sizes of beam hangers, and the number used per beam in 80-pound highway bridges, where the joists, flooring, hand-rails, etc., are all pine. Up, denotes ends upset; N. Up, ends not upset. *Working stress per* □″ = 5 *Tons.* The table is figured for oak floor-beams, so is slightly in excess for pine or iron ones.

TABLE XIV.—Table of sizes of beam hangers, and the number used per beam in 80-pound highway bridges, where the joists and flooring are of oak and remainder of lumber pine, flooring 2½″ thick. Up, denotes ends upset; N. Up, ends not upset. *Working stress per* □″ = 5 *Tons.* The table is

figured for oak floor-beams, so is slightly in excess for pine or iron ones.

TABLE XV.—Table of sizes of beam hangers, and the number used per beam in 80-pound highway bridges where the joists, flooring, hand-rails, etc., are all pine. Up, denotes ends upset; N. Up, ends not upset. *Working stress per* □″ = 4 *Tons.* The table is figured for oak floor-beams, so is slightly in excess for pine or iron ones.

TABLE XVI.—Table of sizes of beam hangers, and the number used per beam in 80-pound highway bridges, where the joists and flooring are of oak and remainder of lumber pine; flooring, 2½″ thick. Up, denotes ends upset; N. Up, ends not upset. *Working stress per* □″ = 4 *Tons.* The table is figured for oak floor-beams, so is slightly in excess for pine or iron ones.

TABLE XVII.—Table of working stresses per square inch in tons of 2,000 lbs. for Highway Bridges—Columns composed of two latticed channel bars.

$$f = \begin{cases} 38500 \text{ for } \square\ \square \\ 38500 \text{ for } \bigcirc\ \square \\ 37800 \text{ for } \bigcirc\ \bigcirc \end{cases}$$

$$\text{Formula } p = \frac{f}{1+\left(\frac{Hr}{C}\right)} \text{ where } p = \text{working stress per } \square'',$$

$$4+\frac{H}{30}$$

$$C = \begin{cases} 5820 \text{ for } \square\ \square \\ 3000 \text{ for } \bigcirc\ \square \\ 1900 \text{ for } \bigcirc\ \bigcirc \end{cases}$$

$$H = \frac{\text{Length}}{\text{Diameter}}.$$

TABLE XVIII.—Table of working stresses per square inch in tons of 2,000 lbs. for Railway Bridges—Columns composed of two latticed channel bars.

$$f = \begin{cases} 38500 \text{ for } \square\ \square \\ 38500 \text{ for } \bigcirc\ \square \\ 37800 \text{ for } \bigcirc\ \bigcirc \end{cases}$$

$$\text{Formula } p = \frac{f}{1+\left(\frac{H^2}{C}\right)} \text{ where } p = \text{working stress per } \square'',$$

$$4+\frac{H}{20}$$

$$C = \begin{cases} 5820 \text{ for } \square\ \square \\ 3000 \text{ for } \bigcirc\ \square \\ 1900 \text{ for } \bigcirc\ \bigcirc \end{cases}$$

$$H = \frac{\text{Length}}{\text{Diameter}}.$$

TABLE XIX.—Table of length, in feet, of lattice bars, weight per foot of same, and weight of rivet heads.

TABLE XX.—Table of Permissible Pressures on Rollers calculated by the formula $p = \sqrt{0.135d}$ where p is the pressure per lineal inch of roller in tons of 2,000 pounds and d the diameter of roller in inches. The first vertical line gives diameters of rollers, the first horizontal line their lengths and the intermediate figures the corresponding permissible pressures.

BROOKLYN BRIDGE.

Everybody is desirous to know something about the prospect of the early completion of the bridge. In order to furnish the public with some assurance on this subject, the trustees requested an expression of opinion from Mr. Roebling, the chief engineer, and they received the following response, a copy of which accompanies the memorial to the Legislature:

BROOKLYN, March 10, 1882.

Hon. Henry C. Murphy, President Board of Trustees New York and Brooklyn Bridge:

DEAR SIR: In response to your letter of March 9, written at the request of Comptroller Campbell, I beg to assure you that the million and a quarter called for in my last estimate will be ample to do all the work enumerated in that estimate, and open the bridge for use. The item of liabilities under outstanding contracts is a fixed fact, and cannot be changed. The estimate of money for work required to complete the bridge is dependent upon the delivery of the steel, and we have Mr. Seller's promise that it will be delivered this summer. The item of materials required for the completion of the bridge and approaches, not yet contracted for, can all be had for the figures given in the detailed estimate. The elevated platforms and rope machinery are simple engineering problems, and their cost is not likely to be increased in any way above the estimates. Respectfully yours,

W. A. ROEBLING, Chief Engineer.

The following statement exhibits an approximate estimate of the total cost of the bridge, when completed, including the amount to be expended, in addition to previous expenditures and the unexpended means provided by former acts of the Legislature, viz.:

February 1, 1882, total expenditure to date	$13,439,590.56
Cash on hand	90,356.49
Amount claimed as due from the cities under acts of the Legislature	500,666.67
Estimated value of lands acquired and to be sold by the trustees	200,000.00
Amount of bonds to be authorized	1,250,000.00
Estimated total cost, exclusive of portals at termini of the bridge	$15,480,613.72

STATEMENT OF THE AMOUNT OF MONEY REQUIRED FOR THE COMPLETION OF THE BRIDGE, BASED ON THE REPORT OF THE CHIEF ENGINEER, FEBRUARY, 1882:

I. Estimated cost of completing the bridge and approaches:		
Liabilities on outstanding contracts for material	$565,322.32	
Estimated cost of material required for the completion of the bridge and approaches other than that contracted for	114,670.60	
Salaries of officers and engineers and cost of labor for completing the bridge and its approaches	117,632.97	
Total	$797,625.89	
Cash on hand February 1, 1882, and due from the cities, less liabilities for salaries and materials received in January	553,557.39	
Amount required for completion of the bridge and approaches in addition to the money on hand and due		$244,068.50
II. Estimated cost of elevated tracks and platforms at the termini:		
1. Cost of elevated platforms, including track arrangements, roofs, waiting rooms, ticket offices, etc	$268,908.00	
2. Cost of machinery, boilers, hauling ropes, etc	37,978.00	
3. Boiler-house	12,000.00	
4. Rolling stock	132,000.00	
Total	$450,886.00	
Ten per cent. for contingencies	45,088.60	
Total	$495,974.60	
Added by Transit Committee	100,000.00	
Total estimated cost of elevated tracks and platforms		$595,974.60
III. Estimated cost of fitting up warehouses under the arches of the New York approach, complete for occupancy		348,184.00
IV. Price of land on Chatham street, New York, adjoining bridge property and agreed to be purchased by the trustees		17,500.00
Total		$1,205,727.10
Added for contingent expenses		44,272.90
Total		$1,250,000.00

[Signed] W. A. ROEBLING, Chief Engineer.

RECENT INVENTIONS.

A novel lamp reflector for railway stations consists of making the shade of a single piece of molded glass, having the form of a truncated pyramid, the several faces of which are each provided with a bull's-eye lens.

A new appliance for railway drawbridges locks the draw in position by the act of shifting a switch to the main line, its normal position being to the siding, and it cannot be so shifted unless the bridge is in proper position in view of a lug upon the bridge which operates a locking bolt to permit the switch lock bolt to secure the bridge. The siding has an incline whereby trains will be brought to a stand, and an automatic switch at the summit of the siding to direct a runaway locomotive into a double inclined siding, where it will be brought to rest. Weighted tilting forked catch levers are arranged between the rails to catch about the axles and stop the locomotive.

A recent safety railway switch has its switch-rail shifted automatically through pivoted levers alongside the track, which are actuated by laterally adjustable bars on the pilot or cow-catcher of the locomotive. A transverse rod, to which one end of each of said levers is pivoted, slides in guide shoes having anti-friction rollers, a hand-operating lever being secured to said rod in one of the guide shoes.

A late improvement in apparatus for generating vapor from liquid hydrocarbons consists essentially of a generating chamber having an internal steam space comprising a series of vertically arranged communicating spheroidal receivers. The arrangement and advantage of these receivers is such as to cause the evaporation of the hydrocarbon flowing over them, according to their volatility—that is to say, the most volatile hydrocarbons are evaporated first and the least volatile last—and to permit the highly heated steam to attack the carbonaceous residua, and form carbonic-oxide and hydrogen gas. The steam is made to flow from the generator under sufficient pressure to carry the hydrocarbons in vaporous form to the point where they are required, and mix the vapor with an air blast to insure complete combustion.

A new device for distributing electrical energy, designed particularly for use in connection with the electric light, comprises an electric circuit divided into branches, with a continuous current generator in the undivided portion thereof. A number of electric lamps are arranged in said branches in a multiple arc, and a secondary battery is located in a branch by itself. The effect of this construction and arrangement is, that when the generator is supplying more electro-motive force than is required by the lamps the excess may develop a charging current through the secondary battery, and when the potential in the circuit falls below the normal, the secondary battery may discharge and supply a current to the lamps, reinforcing that from the generator.

Pile-drivers are now proposed to be constructed with the hammer mounted upon a turn-table turning about a hollow pivot, through which the hammer rope passes, said turn-table resting upon a laterally adjustable platform upon a car platform. The hammer-leaders are formed of T-irons, over which are riveted channel bars, and they are pivoted to the front edge of the turn-table, and are adjusted vertically through brace-frames, the lower ends of which slide on inclined guideways upon the turn-table.

A recently invented truss-bridge has a hollow, wedge-shaped box, with pockets on opposite sides to receive cased ends or chord-sections, and a bolt to adjust the parts; an eccentric on a pin as an adjustable connection of tension chords, and means for adjusting and holding it; counterpart wedges for adjusting posts to chords and braces; and girders of channel iron spaced by blocks, which also serve as sockets for floor joists.

A novel self-recording grade instrument for making sections for railway and other surveys consists of a wheeled prime-mover, which is propelled over the track to be surveyed. Another wheel of the same size, and smaller wheels, connected with a suitable framing, constitutes the carriage for holding the device. Connected with the prime-mover wheel is a small vertical worm, which drives another horizontal wheel carrying on its axis a surface wheel. Upon the latter is carried a vertical wheel or level-motor capable of traversing from the center of the surface wheel to the periphery. An adjustable swivel is in connection with the axle of the said vertical wheel, which may be adjusted by means of two slide rods, with both of which it is connected. This swivel forms the junction with another vertically suspended wheel. This last-named wheel is heavily weighted in one or more of its segments, so as to always remain in one vertical position. If the weighted wheel be moved forward or back ward relatively to the horizontal level of the carriage, the slide rods above referred to are moved backward or forward, in order to enable the machinery of which it is a part to mark the rise and fall of the ground. It follows, therefore, that any change in the level of the carriage will correspondingly affect the position of the level motor, shifting it to one side or the other of the center of the surface wheel, which will then revolve with a greater or less velocity, as it is more or less distant from the center governed by the eccentric. Connected by axles and pinions, this shifting motion is transmitted to a pencil held on a rack-wand. This rack-wand receives its motion from gearing set in motion by the prime-mover wheel, and consequently the wand will cause the pencil to mark or record horizontally right or left of the medial line of the machine, as the angle is up or down during the travel of the carriage, and so that it may act upon a sheet of paper coiled upon a bobbin, and which passing over a curved surface is received upon another similar bobbin. The paper may be graduated and its speed adjusted to any ratio with the speed of the prime-mover. F. B. BROCK.

WASHINGTON, D. C.

COST OF ELECTRIC LIGHTING AS COMPARED WITH GAS.

An American paper states that the Brush Electric Light Company receives $7,400 per annum for lighting Fourteenth street, New York, from Fourth to Fifth avenue, Fifth avenue, and Broadway from Fourteenth to Thirty-fourth street, and the latter street from Fifth avenue to Broadway. In addition, the company, under its contract, also furnishes two groups, six lights each, in Union and Madison squares respectively. The street lamps have been lighted for several months; those in the squares have been in operation for a shorter period. The illumination is said to be fairly satisfactory. The tower lights, however, are effective only upon a small area, and it is also thought that their effect will be still further impaired by the heavy foliage in summer. The total number of gas lamps which it has been possible to extinguish by the substitution of electric lamps in 450. The municipality of New York formerly paid $17.50 per lamp per annum, which is estimated to have been at the rate of about $1 per thousand cubic feet net; but it is stated that that rate was so low that the gas companies did not care about lighting the streets. The gas lights, therefore, cost the city (and probably the producer) $7,525 per annum, and are replaced by the electric light at a cost of $7,400. It is a doubtful point, however, whether the Brush Company, as in London, makes or loses money at this rate. The advertisement alone, in either city, is worth something, and it is just possible that this was taken into account in making the contract. At all events, there seems to be very little margin of difference where gas is supplied at $1 per thousand cubic feet. This, however, it should be clearly understood, is much less than the charge made to private consumers of gas in New York.—*London Architect.*

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S. D. V. BURR.....ASSOCIATE EDITOR.

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Correspondence upon subjects which naturally belongs to the province of this journal is solicited.

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WE hope, in our next issue, to present a full report of the interesting meeting of the American Water-Works Association at Columbus, O., on the 14th and 15th insts. This association of the practical managers of the works for furnishing water to the people of this country is destined, if conducted with the good judgment which has been displayed so far in its organization, to be of inestimable benefit to consumers as well as furnishers of water.

EADS' SHIP RAILWAY.

It is with extreme diffidence that we would venture to dissent from the conclusions to which our valued contemporary of the *Railroad Gazette* would seem to have arrived in his opinion as to the feasibility of this ship railway. Possibly Capt. Eads does not propose to carry his ships over the Isthmus by means of a dozen or so of the railroad tracks now in use, nor use any specified number of the present locomotives. Some time ago a twelve or fourteen-ton engine was brought upon a portion of the main road between this and Boston, and it was called, par excellence, "the big engine," nothing like it having been seen previously, and his sanity would have been questioned who should have attempted to belittle the engine by saying that he expected to see forty-ton engines running upon the same or similar roads, where, indeed, they are running now. Will any one venture to say that we have reached the limit of the capacity either of road or engine?

At a maximum speed of say 6 miles per hour, and on a straight line without curves, it is not too much to expect that engines weighing 100 tons (of 2,000 lbs.), all on the drivers, can be operated; the dimensions and character of track, rail and wheels being made to conform; nor that the bearing wheels of the ship's cradle, say 30-in. wheels, shall be capable of sustaining a weight without injury, at the limited speed named, of 6 tons (2,000 lbs.), if need be. The fact that the cast-iron wheels, found sufficiently safe and cheaply renewed by the thousand yearly for the wants of a rapid speed and traffic, should be estimated at a strength of but 7,500 lbs., is by no means an evidence that the needs of the new service cannot be met by wheels of from 600 to 800 lbs. weight, should it be thought desirable.

Capt. Eads, in his address before the Chamber of Commerce of San Francisco, Aug., 1880, says that under a cradle 350 ft. in length and borne by 12 lines of rails, each rail supporting 115 wheels, or 1,380 wheels in all, a load of 600 tons would give for each wheel but 4¼ tons weight, and the road would suffer no greater stress than some of our heavy traffic roads. But supposing it otherwise, it will be a mere question of dollars to provide the requisite strength. In the letter from Sir Edward Reed, he very conclusively shows that from 4,000 to 6,000 tons will probably be the extreme displacement of a vast majority of the shipping seeking this passage, and it would be entirely uncalled for to provide for the few vessels of greater tonnage which may be launched for other traffic, and his experience in the operation of building and decking ships should give his opinion great weight on this point, as also on the probable weight of the supporting cradle, which for a 4,000-ton ship he estimates at 500 tons, and for a 6,000 ship at 750 tons, but we will double these weights and say for the first cradle 1,000 and the second 1,570 tons.

Capt. Eads estimates 2½ miles only of 2 per cent. grade across the Isthmus, and upon the supposition that the grades cannot be thrown together so as to leave the shorter, heavier ascent to be overcome by stationary power, which might be feasible, we will assume 100 ft. per mile grade as necessary, which therefore becomes the limit to be provided for. This leaves the resistance to be encountered on the track as the only element remaining to be fixed for an estimate of what is *possible*. Taking results of experiments of heavy freight trains on the Erie Railroad, as conducted by McCallum: That 6.5 lbs. per ton (2,000 lbs.) represents the friction of engine and tender without load, friction of loaded cars, 4½ lbs. per ton; gravity of engine and load for 100 ft. grade, additional friction of engine by other resistances than that of the friction of the cars, embracing a side wind pressure of 40 miles velocity for a surface of 350 × 40 ft., and altogether we find the resistance for a 100-ft. grade for a ship and cradle weighing 5,000 tons to be about 250,000 lbs. This is for the maximum grade, which extends but for 2½ miles.

Taking the adhesion of an engine at one-fourth its weight, and the engine weight will be 500 tons. Or, for four engines and tenders, all wheels coupled, 125 tons each say—90-ton engine and 40-ton tender—200 tons of the engine weight being included in the load as estimated. We see nothing in this so formidable as to lead us to question the entire feasibility of a project which has received the unqualified support of men of great experience in matters pertaining to naval constructions of all kinds. Our greatest fear lies in another direction, and that is, that a work which should be American, and the importance of which appears to be better appreciated abroad than at home, will be controlled by foreign capitalists to our national disgrace.

SEWERAGE FOR THE STATE OF NEW YORK.

In ENGINEERING NEWS of Feb. 18, quoting from an article in the *Mail and Express* as to the results of the examinations abroad of the Director of the New York State Survey, and the conclusions to which he had arrived, and the recommendations which he had made, based upon the conclusions, viz., that the "combined" system of sewerage was an utter failure, wherever it had been carried out, and the "separate" system was the more preferable, we had not been favored with a copy of the Report of the gentleman referred to, and our remarks were based entirely upon the tenor of the article in the *Mail and Express*. Mr. Gardiner's Report is now before us, and we beg leave to comment more fully upon his treatment of the subject, in reference to points which had not been brought to our attention in the newspaper article referred to; but even now it would scarcely call for further notice, were it not that the recommendations of Mr. Gardiner are indorsed throughout by the State Board of Health—our highest sanitary authority.

The conflicting opinions of sanitarians on these matters have hitherto tended to unsettle the public mind to a great extent; and while looking for some one method for the proper disposal of sewage, the fact is very much lost sight of that the locality and its surroundings should control this matter to a great extent, and no engineer at the present day can be found to advocate any known method as practically applicable to all localities. And yet, recognizing the fact that the prompt removal of sewage of *all* kinds from the vicinity of dwellings is a measure of the first necessity, that method by which this essential can be effected with the least possibility of its disarrangement through the neglect of personal agents or employés is undoubtedly the best; and, putting expense out of the question, no one can have the hardihood to deny that the water carriage system does offer this advantage over any or all methods which have been proposed to this end. But in many localities this method, with all its theoretical advantages, is practically debarred; and hence we are driven of necessity to look to other means, not as the best, but as the most practicable, in such cases.

The paper referred to, however, settles all that has heretofore been a subject of doubt in this most intricate subject, and one which has been entirely misunderstood, it would seem, until now by some of the most enlightened minds of the age.

The paper is entitled "No. 42, State Board of Health of New York, Report on the Methods of Sewerage for cities and large villages in the State of New York, by James T. Gardiner, Director of the New York State Survey, Member State Board of Health."

As conducive to perspicuity, we propose to take the headings of the subject as he has treated them, *seriatim*.

In the first place, all that is said in the opening of the paper of the dangers of the cesspool and privy vault we heartily indorse, and so far as we know, modern sanitation has uniformly condemned them as fraught with mischief, and yet to this day, as in Paris, a proper system of police and inspection will mitigate the evils, which at first sight, and on theoretical principles, would seem to be almost insurmountable, and render their use under proper management not incompatable with a low death rate. The use of cesspools in some shape, removed from the house on farms or very small settlements, cannot well be avoided in the country, where an attempt to apply the alternative of the semi-barbarous pail system, would be attended with the very evils sought to be removed, and result in the house waste and sewage being scattered or disposed of in an equal or even more objectionable manner somewhere else on the premises.

After disposing of the cesspools and vaults, the first method which is taken up for consideration is the *dry removal*. Of this method, two means are alluded to, the dry earth closet, and the "pail" system. The first, for reasons stated, is no longer recommended, and as showing the uncertainty of expert testimony, we would state that no longer ago than 1870 this very dry earth closet method was advocated by the present advocate of the separate water carriage system, Col. Waring, as destined to supersede all other methods entirely, especially in villas and small settlements. Water carriage was condemned even in cities, and the dry-earth closet lauded as the system of the future, and even the manurial value of the product, now found to be worthless, was stated as one of its advantages over that of any method of water carriage. Companies were formed to manufacture the utensils; agents appointed throughout the length and breadth of the land to sing their praises and to sell the patent rights and circulate the sensational writings of its chief apostle. Ten years have sufficed to explode this fallacy, and who shall say that the next great boon which is offered in its stead shall be longer lived? The disgusting tub, cask or "pail" system is recommended for all villages and towns without public water supply. And we may say cities are included possibly, for Manchester with 500,000 inhabitants is cited as a successful example to follow.

In Manchester, he says, the "pail" is of galvanized iron of a capacity of ten gallons. "Each tub is covered with a close-fitting double lid before removal." "Beside each tub is a very simple ash sifter, from which the ashes fall to help deodorize its contents." "The tubs are removed in the daytime without offensive odor." In Rochdale, a city of 70,000 inhabitants, "the manure sells for four-fifths of the cost of its collection and preparation," etc. He admits that "from false economy or neglect, these pails may not be attended to at sufficiently frequent intervals," but adds "that the small size of the tubs puts a narrow limit and compels attention." Possibly—though we may very naturally ask—from whom? and point to the above-described process as requiring no further comment. The prime advantage of this highly-savory proceeding, it seems, is "the cheapness of the plan and the smallness of the original outlay of money and brains." We hazard the opinion that it is doubtful where the economy of brains is most manifest—in the user or the advocates of such a method.

Water Carriage, or Sewerage.—This is divided into two heads—the *combined* and the *separate* systems. So much has been written on these that we refrain from more than a brief notice of their characteristics. By the first, all sewage whatever, including excreta, house slops and street sewage, with a proportion of the rainfall, is conveyed to some remote outlet by a single channel of discharge. The separate system, on the contrary, requires a line of sewers devoted exclusively to the house sewage, while the sewage from other sources and the storm waters must have their separate lines of sewers, or, as in Memphis, trust to their getting off the surface or out of sight as they best may.

After explaining the above systems, Mr. Gardiner, big with an idea of which he delivers himself "that engineers have made the mistake of confounding sewer gas with the cause of disease, and hence their mistake in supposing that the ventilation of sewers by diluting this gas would prove effectual in weakening the sources of disease," proceeds to say, "that *no such gas as sewer gas exists* (the italics are his) *and that there is absolutely no proof that the diseases which attend the admission of sewer air into a dwelling are produced by gases.*" This is a quibble, unworthy the State Board of Health. No engineer of the present day believes that gas however generated can be considered as the *source* of disease,

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or in itself producing disease, but that it may be the vehicle for disseminating disease germs—whatever they may be—on the principle that the gas generated by the decomposition of animal matter may be the pabulum which nourishes these lower organisms—this they undoubtedly believe, and hence that ventilation, which is dilution of this gas, is believed by them, as we supposed by physicians generally, to be a means for lessening the spread of disease, as weakening the element which is essential to its increase—in other words, sewer gas is an efficient cause, but not the final cause, of disease. Are bacteria supposed to be nourished by any of the gases known to chemists as the result of decomposition? Is it not a fact—or rather it is a fact—that in addition to the known gases of decomposition, susceptible to chemical tests, there is a something which for lack of a better name we may call organic vapor, without which none of the known gases are productive of *disease*, although, when in excess, they may kill. Sewer-air may indeed be a better name than sewer-gas; but a mere change of name will not change its properties nor its capabilities for mischief, nor the sense in which we use the word.

He says further, "that the sewer-air may bring the germs of disease into dwellings, while the foul gases of decomposition may or may not be present." This may be all very true, but there is some assumption about it, and space will not at present admit of its discussion. We would remark, however, that the attempt to weaken the value of ventilation will be a backward step in hygiene, with the accumulated evidence in support of its value, now in our possession. It seems that large sewers, being built of brick, "their porous walls furnish the favorable soil for these deadly organisms, *and the ammonia of sewage supplying the manure essential to their full development.*" We might properly ask, why is it, if sewer gas be such an unmeaning word, that one of its most obvious constituents, ammonia, should be selected as the chief element for the nutrition of disease germs? "Every device," he says, "of engineering has been exhausted to keep large sewers well ventilated, but the air from them is still deadly." All this, and much more, of simple dogmatism is the prelude to his summing up in this sweeping assertion, "that from a sanitary point of view the "combined" system of sewerage is a failure" . . . . . "and those cities which have already spent large sums in completing combined sewers, must either continue to suffer from the evils of sewer poison or incur the further expense of a separate small system for carrying sewage only, retaining the large sewers for storm water."

The separate system then comes up for consideration, if that may be called consideration which consists merely in giving expression to a foregone conclusion, which considers the separate system not only the best for all localities, but by far the cheaper method, and as we have already gone over the same grounds repeatedly in discussing this question, and shown the fallacy of the arguments adduced in support of the separate system for all localities, and have, in addition, published in ENGINEERING NEWS a most thorough and exhaustive treatment of the entire subject by one who, in addition to great natural ability, has made the subject a life-time study, both here and abroad, we refer to Mr. R. Hering, of Philadelphia—we now follow this writer no further, but as his conclusions have been adopted by the State Board of Health and a ukase issued to that effect, and, so far as lies in the power of such Board, they are law—we have a word or two to offer upon this new phase of the subject.

We have a high respect for boards of health on general principles, that is to say, in the selection of the individuals composing them, and it is to be presumed that the appointing power sought for the highest possible scientific attainments in its members, coupled with such experience as torender the science of the schools of practical value, and, at the same time, for its proper exercise, in a matter of so much importance, a degree of calm, judicious and comprehensive judgment, flavored with strong common sense, which should render the individual unlikely to be captured or carried away by a craze which had plausibility enough in its inception to unsettle the better judgment of the average man; in a word, the individuals should be such marked men in the community as to render their decisions unassailable, and not open even to the suspicion of having been influenced by any individual persistency, or the weakness which not unfrequently induces a board of officers to yield for the sake of harmonious action to an active element in its midst ambitious of leading in great reforms. If our State Board of Health be thus constituted, happy are we, and what now may appear dark and mysterious in its decisions will come out brighter and brighter the more it is examined, and the more light that is shed upon it will but exhibit in a clearer view that which in our ignorance and shortsightedness we mistook for imbecility, was in truth the profundity of wisdom.

SANITARY PROTECTION.

The first annual report of the London Sanitary Protection Society discloses facts which supply ample grounds for the existence of such an association. The engineers' reports show that, of the total number of houses inspected, in 6 per cent. the drains were entirely stopped up, and all the sewage soaked into the ground under the basement of the house, there being no connection whatever with the sewer; that in about one-third the soil-pipes were leaky, allowing sewer-gas to escape into the house; that in about one-third the overflow pipes from the cisterns discharged into a soil-pipe or drain. More than half the houses inspected had waste-pipes from baths or sinks connected directly with soil-pipes or drains, generally, it was true, through syphon traps; but if any of the appliances should be disused for a time, and the water in the tap dry up, those waste-pipes would provide a direct channel for sewer-gas into the house. It is certainly alarming that, out of the total number of cases inspected, 6 per cent. of the houses should be absolutely pestiferous. It is the merest chance that such houses have not proved hotbeds of disease. In a much larger proportion there are defects in the general arrangements and drainage of the houses which ought to fill us with alarm. We shall not be surprised if, should the association continue long enough, the bad state of London houses will lead to an official inspection of houses in all towns. By such an inspection as that afforded by the society, the spread of typhoid fever will be in a great measure prevented. It is a satisfactory sign of the appreciation of the efforts of the society that some public buildings have already been placed in their charge with regard to their sanitary arrangements.

PERSONAL.

MR. E. COMBOUL, chief engineer of the New York, Texas & Mexican Railroad, has resigned.

MR. T. A. HILL has been appointed chief engineer of the Austin & Northwestern (N. G.) Railroad. Headquarters at Austin, Texas.

ISAAC WORNEY, an eminent engineer, of Pittsburgh, Pa., has been appointed Superintendent of Public Works by the Citizen's Council of San Antonio, Texas.

ZACHARIAH ALLEN, long one of the leading men of Rhode Island, died in Providence on Friday night, the 17th, aged 87. He had filled many important positions. At the time of his death he was president of the Rhode Island Historical Society. He wrote "The Science of Mechanics" and "The Philosophy of the Mechanics of Nature."

A DISPATCH dated City of Mexico, March 14, says, James Pyett, an American engineer, with six Mexicans, coming down a steep grade on a hand-car on the National Railroad, turned suddenly upon a bridge where two men were. One jumped. The car containing the others was thrown into the chasm. Pyett and three Mexicans were instantly killed. The others were fatally hurt.

G. CLINTON GARDNER, General Manager of the Mexican National & Texas-Mexican Railway has issued the following general order: Engineer S. T. Fuller, of the Northern Division of the Texas-Mexican Railway Company, has been appointed general superintendent and chief engineer of the Northern Division of the Mexican National Construction Company and the Mexican National Railway Company, as also general superintendent and chief engineer of the Texas-Mexican Railway. His duties as general superintendent and chief engineer will extend over all the lines of these companies north of San Luis Potosi, including the Matamoros Division. Superintendent W. W. Hungerford has been appointed superintendent of construction, and will report direct to General Superintendent and Chief Engineer Fuller, taking personal charge of the movement of trains and the track work on Lampazos Division, with such other duties as may be assigned to him. Principal Assistant Engineer E. Miller will take personal charge of location and surveys, with such construction work as may be assigned to him, reporting direct to General Superintendent and Chief Engineer Fuller.

SOLOMON WHITE ROBERTS, a well-known civil engineer, died at Atlantic City, N. J., on the 23d. Mr. Roberts was born in Philadelphia, Aug. 3, 1811. At the age of sixteen he left school and went to Mauch Chunk, where he received a position as assistant under his uncle, Josiah White, then the superintendent of the Lehigh Coal and Navigation Company. Under Mr. White's direction, in 1827, was constructed the first railroad in Pennsylvania, extending from Summit Hill to Mauch Chunk, a distance of nine miles. In 1829 Mr. Roberts entered the service of the State as an engineer, and two years later undertook the work on the Portage Railroad.

In 1836 he entered the service of the Philadelphia & Reading Railroad, and for two years remained abroad superintending the manufacture of railroad iron. From 1838 to 1841 he was chief engineer of the Catawissa Railroad. In 1842 he was elected president of the Philadelphia, Germantown & Norristown Railroad Company, and from 1842 to 1845 he was the president of the Schuylkill Navigation Company. In 1848 he was elected to the State Assembly and secured important legislation in aid of the Pennsylvania Railroad Company, in which line he was largely interested. From 1848 to 1856 Mr. Roberts was the chief engineer of the road. He then accepted the same position on the North Pennsylvania Line and continued there until the road was merged into the Reading Railroad system.

ENGINEERS' SOCIETIES.

THE INSTITUTION OF CIVIL ENGINEERS.

At the ordinary meeting on Tuesday, February 28, Mr. E. Woods, vice-president, in the chair, the paper read was on "Steel for Structures," by Mr. Ewing Matheson, M. Inst. C. E. The object of this paper was to state the present position which steel occupied, as compared with iron, as a material of construction; and to examine the reasons why, while steel was rapidly superseding iron for ships and boilers, it was so seldom used for bridges. Steel possessed the important advantage of a strength one and a-half to twice that of iron, as well as superior elasticity and ductility; and, owing to the method of manufacture, plates and bars of the usual kind could be made of steel in much larger pieces than was possible with iron, thus avoiding the numerous joints which the smaller pieces involved. The special treatment necessary for steel could soon be learned by workmen accustomed to iron, and the tools and machinery of a factory could be used for either metal. In regard to wasting by rust, sufficient time had hardly elapsed to prove positively the durability of steel as compared with iron, but at present it appeared as if the difference, if any, was in favor of steel. Because of its greater strength, structures equal to iron could be made of less weight in steel; and in regard to ships, this saving allowed a corresponding increase in cargo-carrying capacity, or a reduced immersion. In boilers, plates, whether of steel or of iron, could not conveniently be of more than a certain thickness, and the working pressure was limited accordingly; but the superior strength of steel permitted a working pressure of steam one-third greater than in boilers of iron, thus allowing a saving in the space occupied for a given power, and greater economy in fuel. In regard to girders or bridges, if strength and elasticity were assured, there was not the same necessity for the great ductility which in ships was so important to resist concussion; but the rules of the Board of Trade, which controlled railway structures in this country, allowed working strains on the parts of steel bridges based on the extremely ductile steel used for ships. That was to say, while the maximum strain allowed on iron was 5 tons per square inch of sectional area, a strain of only 6½ tons was allowed on steel. By this limitation, the engineer, in designing bridges, was unable to take full advantage of steel; and as, moreover, for various secondary reasons, the thickness of parts in a steel structure could not be reduced, in proportion to those of an iron structure, quite so much as even the permitted strains allowed, bridges of moderate span could not be made so cheaply of steel as of iron, so long as the cost of the material exceeded, as at present, that of iron in a proportion equal to that of the greater strains permitted. Until the present time, the cases in which steel had been profitably used were those in which, because of difficult transport in new countries, lightness was of great value, and those where, owing to the great length of span, the weight of the material itself, as distinct from the dead and moving load it had to carry, imposed the principal strain, a compound saving being thus afforded by the use of steel. In this way, while a saving in weight of only 12 per cent could be obtained in a bridge of 50-ft. span, a saving of 30 per cent. could be obtained in a bridge of 500-ft. span. With the present prices of iron and steel, there would be a loss by using steel in the small span and a gain by using it in the large span. But while there might be no immediate pecuniary saving by using steel, there was, owing to the very moderate strains permitted on this new material, a much greater margin of safety than in iron. Hence the question arose whether, even although the cost of steel bridges of moderate span might be greater than that of iron bridges, they should not be preferred, and their use enforced, because, if measured by units of strength and durability, as well as of money, they would be cheaper eventually.

There were several means by which the use of steel might be extended. In the first place, the experience gained during the last few years, as to the certainty of quality and the readiness with which it could be treated, had not yet spread to all concerned, especially to engineers abroad, who

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awaited some authoritative affirmation to set against the records of early mistakes, misapplications and failures. The proper treatment of steel had now been thoroughly investigated, and the circumstances under which the metal was damaged, by punching holes and other manipulation, were well understood. But there was also needed some ready means of verifying quality. This was far more necessary in steel than in iron, because in the latter the range within which strength might vary was only one-sixth, whereas steel had a much wider range. Again, the mere fact that iron had been rolled into shape insured a certain minimum of quality, while if steel chanced to be bad it might be one-half weaker than was wanted. An authoritative brand or hall-mark seemed necessary, if steel was to be universally accepted, and the author suggested that some mark should be adopted, as denoting quality and kind, the addition of the particular trade-mark of each maker serving as a warranty. But in order to encourage a further use of steel, the Board of Trade rules should be altered. While a certain minimum of strength and ductility might be demanded, the present limits to the maximum straining should be amended so that, instead of 6½ tons per square inch, 8 tons might be allowed, an increase amply justified by the experience acquired during the last few years. If this was done the greater demand would almost certainly have the effect of bringing the price nearer to that of iron, as had been the case with rails. The author set forth the present rules of the English Admiralty and Lloyd's in regard to steel for ships, and directed attention to the different rules of the French Admiralty, to exemplify the alterations which he proposed. As it was by means of a Royal Commission that the present strains on steel were permitted it was time that another commission should be appointed to inquire into the facts more recently acquired and to grant more liberal rules for the future. With an extension of the present limit of 6½ tons there would be such a demand as would lead to improvements in the manufacture, increase the output and reduce the price of steel. The whole calculation would then be altered, and when steel might not only be worked to 8 tons strain per square inch, but the difference in price over iron was less than it was now with 6½ tons, then, but not till then, would the era of steel structures have arrived.

LIVERPOOL ENGINEERING SOCIETY, ROYAL INSTITUTION, COLQUITT STREET.

At a meeting of the above society held on Wednesday evening, March 1, Mr. C. S. Pain, Vice-President, in the chair, a paper on "Heating and Ventilation" was read by Mr. W. E. Mills.

The author, in introducing his subject, pointed out the necessity that existed for a scientific study of its principles and laws, as evidenced by the fact that upwards of 120,000 deaths occur annually in the United Kingdom from what may be called preventible diseases, a large proportion being from consumption, bronchitis, etc., and mainly due from neglect or ignorance of the laws of ventilation.

The earliest means of heating—viz., by a pan of charcoal, or live coals, afterward improved by being placed in a box or grate—was then described, and this arrangement with some modifications in form, but none in principle, was shown to be the ordinary household fire-grate of the present day.

Large buildings requiring special appliances for economizing and distributing the heat produced by combustion, stoves were introduced, which for heating answered well, but by consuming the oxygen of the air, destroyed the vital principle, and from a ventilating point of view were consequently inadmissible.

Stoves and fire-grates shared alike the disadvantages of being too local in their influence. Where heat was required to be conveyed to a distance, some other means of doing so than by a stove or grate was imperative. Hot water naturally suggested itself, and the "low pressure" and "high pressure" systems were described. Neither were to be taken as satisfactory, unless provision were made for introducing fresh air under the pipes, so as to fulfill the requirements of proper ventilation.

The author pointed out that it was a great fallacy to suppose that air to be *fresh* must of necessity be *cold*. All air admitted to a room or building should first be moderately warmed. This could be effected by means of ventilating grates, the principle of which consisted of a chamber formed behind the ordinary fire-grate, supplied with air from the exterior of the building, which, after being warmed, was delivered into the apartment. The principal kinds were the Galton, the Longden, the Boyd and the Mancher, each set of which were briefly described.

Gas stoves the author condemned, as, although convenient, the fumes given off were very deleterious, and a large amount of gas was consumed for very little effective result.

The system patented by Mr. Lewis W. Leeds, of Philadelphia, was next described. Steam was employed as the heating medium, supplied to coils or radiators, of specially formed pipes, the theory being that the proper way to warm a room was by radiation from the floor and walls.

With regard to ventilation, the author showed that it was necessary to change the air of a room several times in each hour, according to the number of occupants, gaslights, etc., allowing for each person 900 cubic feet per hour, for a gaslight 480, and for a fireplace 48,000.

The cause of draughts was then explained, the remedy being to admit a copious supply of fresh air at the lower part of the room, and draw off the foul and vitiated air at the upper.

Pott's Ventilating Cornice and Tobin's Vertical Tubes were then treated of, and their advantages and disadvantages compared.

The author concluded his paper with a few rules as to the proportion of inlet and outlet for ventilating shafts, the amount of radiation from hot-water pipes, and the cooling effect exerted by windows.

An interesting discussion followed the reading of the paper. The Vice-President announced that at the next meeting of the Society, to be held on Wednesday, March 15, a paper on "Paper Machinery," would be read.

THE HISTORY AND STATISTICS OF AMERICAN WATER-WORKS.

BY J. JAMES R. CROES, M. AM. SOC. C. E.

Continued from page 91.

CCXLVI.—SALEM, OR.

Salem, Oregon, in lat. 44° 56′ N., long. 123° W., is on the east bank of the Willamette River. It possesses a valuable water-power from Mill Creek, which empties into the river near this point.

Settled in 1840, it was incorporated in 1846. Water-works were built by a private company, after the plans and under the superintendence of W. F. Boothby, taking the water from the Willamette River and pumping it 87 ft. by a Blake pump of 18-in. steam and 12-in. water cylinder of 24-in. stroke into a reservoir of stone and timber holding 180,000 gallons.

Distribution is by 6 miles of cast-iron pipe of 6-in. to 3-in. diameter, with 35 fire hydrants, 25 gates and 250 taps. The town pays $1,500 per year for use of hydrants. Service pipes are of galvanized iron. The population in 1880 was 5,009. The daily consumption is 360,000 gallons.

The capital stock is $90,000. The works have cost $50,676.11, including purchase of water-power and opposition works in 1881. There is no debt. The gross receipts have been $54,971.18. The expenses in 1880 were $3,000.92 and the receipts $5,595.11.

W. F. Boothby is President and David Allen Secretary of the Company.

CCXLVII.—PIOCHE.

Pioche, Nevada, is in lat. 37° 50′ N., long. 114° 30′ W., in a cañon of the Cordilleras, 7,000 ft. above sea level. Was settled in 1869.

Water-works were built by a private company in 1872, after plans of George Coffee, taking water from springs and catching it in wooden tanks holding 200,000 gallons, 312 ft. above the town.

Distribution is by sheet-iron pipe, double riveted and coated with asphalte, of which 8 miles are laid, of from 8 to 3-in. diameter, with 20 fire hydrants and 45 taps. The town does not pay for use of water. Service pipes are of gas pipe. The population is about 900 and the daily consumption 10,000 gallons. The works cost $150,000. No further financial statements are given.

R. H. Elam is the Superintendent.

CCXLVIII.—PORT BYRON.

Port Byron, N. Y., in lat. 43° 2′ N.. long. 76° 40′ W.. at the outlet of Owasco Lake, is in the valley of the Owasco, with hills to east and west from 100 to 75 ft. high.

Settled in 1797, it was incorporated as a village in 1837. Water-works were built by the village in 1872 for fire purposes only, taking the supply from the lake, and pumping by water-power through a 4-in. pipe into a reservoir 150 by 55 ft. and 12 ft. deep, excavated in clay and without lining, and 175 ft. above the village.

A 6-in. pipe connects with the force main near the pump, and extends through the main street. A 4-in. pipe from the reservoir passes through the streets on the west side.

The pipes are of cast iron. About 3 miles are in use, with 24 fire hydrants, 3 gates and 26 taps. The water is not used for drinking or household purposes.

The population in 1880 was 1,950. The consumption is not known. The works cost $10,000, and there is a bonded debt of $8,000 at 6 per cent. interest. Further financial statements are not given.

Charles M. Storms is Water Commissioner.

CCXLIX.—BIG RAPIDS.

Big Rapids, Michigan, in lat. 43° 45′ N., long. 85° 45′ W., is on the Muskegan River, on nearly level ground, the greatest difference of elevation being 35 ft.

It was settled in 1860. Water-works were built by the town in 1871. The supply is taken from the river through a gravel filter crib and pumped directly into the mains by a Holly engine and pumps erected in 1871, and two Blake pumps of 20-in. steam and 16-in. water cylinders, with 24-in. stroke, erected in 1880. The ordinary pressure is 65 lbs., and the fire pressure 100 lbs.

Distribution was at first by wooden pipe, which was unsatisfactory, and was replaced by cast-iron pipe, of which 3¼ miles are in use of from 8-in. to 4-in. diameter, with 35 hydrants, 4 gates and 209 taps. Service pipes are of lead.

The population in 1880 was 3,750. The daily consumption in 1881 was 264,000 gallons.

The works have cost $90,000. Further financial statistics are not given.

George H. Lincoln is the Superintendent.

CCL.—NEW BRUNSWICK.

New Brunswick, New Jersey, in lat. 40° 49′ N., long. 70° 49′ W., is on the Raritan River. The crest of a red shale bluff along the river recedes at the site of the city, forming a gently sloping amphitheatre of about a mile in diameter.

The city was incorporated in 1784. Water-works were built by the city in 1866 after plans of E. Willard Smith, C. E., and under the superintendence of Thomas N. Doughty, C. E., taking the supply from Lawrence's Brook, a stream south of the city, with 43 square miles water-shed. A stone dam 15 ft. high and 184 ft. long creates an impounding reservoir and also furnishes power to a 54-in. American turbine wheel, which drives a 12-in. pump which lifts the water 130 ft. to the distributing reservoir built in excavation and embankment, with two basins each 300 ft. square and 15 ft. deep. A Selden direct acting steam pump with 36-in. steam cylinder and 22-in. plunger has since been added.

Distribution is by wrough-iron and cement pipe and some cast-iron. Twenty miles are in use of from 16 to 4-in. diameter, with 166 fire hydrants, 209 gates, 1,250 taps and 59 meters.

The city contributes $50 per year for each hydrant out of general taxation. Service pipes are of lead and of galvanized iron. The population in 1880 was 17,167 and the daily consumption 1,264,000 gallons.

The works have cost $440,000, and the gross receipts to Dec. 31, 1881, had been $283,454.66.

The expenses in 1880 were $14,901.59, and the receipts $42,754.35. The debt is not given.

The works are managed by a board of water commissioners. M. N. Oviatt was Superintendent prior to January, 1882. A. J. Jones, the Treasurer since 1873, is now Superintendent also.

(TO BE CONTINUED.)

ACKNOWLEDGMENTS.—The receipt of statistics, as follows, is acknowledged with thanks: From B. E. Lehman, superintendent, statistics and water rates of the water-works of South Bethleham, Penna. From O. R. Tyler, superintendent, statistics of the water-works of Torrington, Conn. From A. J. Jones, superintendent, statistics of the water-works of New Brunswick, N. J. From W. H. Glore, superintendent, statistics of Covington (Ky.) water-works. From Fred E. Hoyt, superintendent and secretary, ninth annual report of East Saginaw (Mich.) water commissioners. From Edwin Darling, superintendent, second annual report of Pawtucket (R. I.) water commissioners. From F. W. Lougee, secretary, statistics and rates of the Petaluma (Cal.) Water-works Co. From C. E. Judson, superintendent and engineer, statistics of the Scranton (Pa.) Water-works Co. From M. Coryell, superintendent, fifth report of Lambertville (N. J.) Water Co. From Robert K. Martin, chief engineer, report of Baltimore water department for 1881. From Louis Le Sage, superintendent, report of the Montreal Water-works for 1881. From Welton & Bonnett, civil engineers, fifteenth report of the Waterbury (Conn.) water commissioners. From A. L. Tompkins, statistics of the water-works of Le Roy, N. Y. From W. S. Bush, superintendent, statistics and water rates of the water-works of Westfield, Mass. From the water commissioners, statistics of the water-works of New Britain, Conn. From W. F. McCue, superintendent, statistics and water rates of the water-works of Ottumwa, Ia. From James B. Simes, president, statistics of the water-works of Downingtown, Pa. From S. S. Graves, superintendent, statistics of the water-works of Geneva, N. Y. From W. E. McClintock, city engineer, report of the city engineer and superintendent of sewers for 1881 of Chelsea, Mass.

CORRECTIONS.—March 11, p. 84, *Middletown*, Conn. The drainage area of the reservoir is 1½ sq. m. The filter wall is a double wall of *stone* filled in with small stone and gravel. March 18, p. 91, *St. Charles*, Mo. The cost of the works *was* $160,000, *not* $80,000 *as erroneously published.*

The circular sent to Tonawanda, N. Y., being returned unclaimed, it is supposed that there are no water-works there.